

# Cyclical Effects of Bank Capital Requirements with Imperfect Credit Markets

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The World Bank  
Development Economics Vice Presidency  
September 2009



## Abstract

This paper analyzes the cyclical effects of bank capital requirements in a simple model with credit market imperfections. Lending rates are set as a premium over the cost of borrowing from the central bank, with the premium itself depending on firms' effective collateral. Basel I- and Basel II-type regulatory regimes are defined and a capital channel is introduced through a signaling effect of capital buffers on the cost of bank deposits.

The macroeconomic effects of various shocks (a drop in output, an increase in the refinance rate, and a rise in the capital adequacy ratio) are analyzed, under both binding and nonbinding capital requirements. Factors affecting the procyclicality of each regime (defined in terms of the behavior of the risk premium) are also identified and policy implications are discussed.

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This paper—a product of the Economics Department Vice Presidency—is part of a larger effort in the department to investigate regulatory reforms in the financial sector after the crisis. Policy Research Working Papers are also posted on the Web at <http://econ.worldbank.org>. The authors may be contacted at [pierre-richard.agenor@manchester.ac.uk](mailto:pierre-richard.agenor@manchester.ac.uk) and [Lpereiradasilva@worldbank.org](mailto:Lpereiradasilva@worldbank.org)

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**JEL Classification Numbers:** E44, H52, G28.

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# Contents

<b>1</b>	<b>Introduction</b>	<b>3</b>
<b>2</b>	<b>The Model</b>	<b>6</b>
2.1	Firms . . . . .	7
2.2	Households . . . . .	9
2.3	Commercial Bank . . . . .	11
2.3.1	Interest Rate Pricing Rules . . . . .	11
2.3.2	Capital Requirements . . . . .	14
2.3.3	Borrowing from the Central Bank . . . . .	16
2.4	Central Bank . . . . .	17
2.5	Market-Clearing Conditions . . . . .	17
<b>3</b>	<b>Non-Binding Capital Requirements</b>	<b>18</b>
3.1	Negative Supply Shock . . . . .	21
3.2	Increase in Official Refinance Rate . . . . .	25
3.3	Increase in Capital Adequacy Ratio . . . . .	27
<b>4</b>	<b>Binding Capital Requirements</b>	<b>28</b>
4.1	Constant Risk Weights . . . . .	29
4.2	Endogenous Risk Weights . . . . .	32
<b>5</b>	<b>Concluding Remarks</b>	<b>35</b>
	<b>References</b>	<b>39</b>
	<b>Figures 1 to 12</b>	<b>42</b>
	<b>Appendix</b>	<b>43</b>

# 1 Introduction

The global financial crisis triggered by the collapse of the subprime mortgage market in the United States has led to a reassessment of the policies and rules that have allowed the buildup of financial fragilities. The regulatory framework, and the distortions in bank behavior and the financial intermediation process that it has created, have come under renewed scrutiny. Indeed, it is now well recognized that the Basel I regulatory capital regime that U.S. banks were subject to gave them strong incentives to reduce required capital by shifting loans off their balance sheets.<sup>1</sup> Banks turned to an “originate and distribute” model, in which standardized loans, mostly high-risk mortgages—involving no money down, interest only or less as the initial payment, with no documentation on borrowers’ capacity to pay, and initial “teaser” interest rates that would adjust upward even if market rates remained constant—could be bundled and sold as securities, thereby leaving the originating bank free to use its capital elsewhere. As the housing market deteriorated, and uncertainty about the underlying value of subprime mortgage-backed securities mounted, efforts to maintain capital adequacy led to massive deleveraging, capital hoarding, liquidity shortages, and contractions in credit supply, with adverse consequences for the functioning of both real and financial markets (see Calomiris (2008), and Kashyap, Rajan, and Stein (2009)).

Since consultations on the Basel II accord started, and since its eventual adoption in 2004, there has been a broader debate on the procyclicality effect of prudential and regulatory rules and practices.<sup>2</sup> With Basel II, capital

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<sup>1</sup>The 1988 Basel I Accord prescribed that banks hold capital of at least 8 percent of their risk-weighted assets. Critics noted early on that it treated all corporate credits alike and thereby invited regulatory arbitrage, and that it failed to take account of the distortions induced by capital regulation.

<sup>2</sup>The 2004 Basel II allows banks to use their internal models to assess the riskiness of

requirements are based on asset *quality* rather than only on asset *type*, and banks must use “marking to market” to price assets, rather than book value. As the rules make bank capital requirements more sensitive to changes in the banks’ risk exposure, and as the riskiness of loan books changes over the business cycle, the required regulatory capital varies with the business cycle. For instance, when asset prices start declining, banks may be forced to undertake continuous writedowns (accompanied by increased provisioning), and this raises their need for capital. Capital requirements may therefore increase in a cyclical downturn. If banks are highly leveraged, to maintain their capital ratio during a recession, they must either raise capital (which is difficult and/or costly in bad times) or cut back their lending, which in turn tends to amplify the downturn. Thus, the introduction of risk-sensitive capital charges may not only unduly increase the volatility of regulatory capital, it may also (by limiting banks’ ability to lend) exacerbate an economic downturn.

Most existing studies of the cyclicity of capital regulatory regimes, both theoretical and empirical, are based on industrialized countries.<sup>3</sup> However, the pervasiveness of financial market imperfections in developing countries, coupled with their greater vulnerability to shocks, makes a focus on these countries warranted. For middle-income countries, in particular, these im-

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their portfolios and to determine their required capital cushion—provided that their internal model is validated by the regulatory authority. It also acknowledges the importance of two complementary mechanisms to safeguard financial stability, namely supervision and market discipline.

<sup>3</sup>For empirical studies on industrial countries, see for instance Ayuso, Pérez, and Saurina (2004), Bikker (2004), Gordy and Howells (2006), and Van Roy (2008). For theoretical contributions, see Blum and Hellwig (1995), Zicchino (2005), Cecchetti and Li (2008), and the literature surveys by Drumond (2008), and VanHoose (2008). Pereira (2009) provides references to the limited literature on middle-income countries. He also provides a critical review of the empirical evidence, based on the general equilibrium implications of the present paper.

perfections cover a broad spectrum: underdeveloped capital markets, which imply limited alternatives (such as corporate bonds and commercial paper) to bank credit; limited competition among banks; more severe asymmetric information problems, which make screening out good from bad credit risks difficult and fosters collateralized lending; a pervasive role of government in banking, both directly or indirectly; uncertain public guarantees; inadequate disclosure and transparency, coupled with weak supervision and a limited ability to enforce prudential regulations; weak property rights and an inefficient legal system, which makes contract enforcement difficult and also encourages collateralized lending; and a volatile economic environment, which increases exposure to adverse shocks and magnifies (all else equal) both the possibility of default by borrowers and the risk of bankruptcy of financial institutions. One implication is that a large majority of small and medium-size firms (operating mostly in the informal sector) are simply squeezed out of the credit market, whereas those who do have access to it—well-established firms, often belonging to members of the local elite—face an elastic supply of loans and borrow at terms that depend on their ability to pledge collateral. Credit rationing—which results fundamentally from the fact that inadequate collateral would have led to prohibitive rates—is therefore largely “exogenous.” A second implication is the importance of the cost channel, which becomes a key part of the monetary transmission mechanism.<sup>4</sup> The goal of this paper is to analyze the cyclical effects of Basel I- and Basel II-type capital standards in a simple macroeconomic model that captures some of these financial features and implications. As it turns out, a key variable in the determination of macroeconomic equilibrium is the risk premium that banks charge their

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<sup>4</sup>The direct effect of lending rates on firms’ marginal production costs is a common feature of developing economies, and there is evidence that it may be important also in industrial countries. See the references in Agénor and Alper (2009), for instance.

customers, depending on the effective collateral that they can pledge.

The paper continues as follows. Section II presents the model. Basel I- and Basel II-type regulatory capital regimes are defined, the latter by linking the risk premium on loans to risk weights. A “bank capital channel” is accounted for by introducing a signaling effect of capital buffers on bank deposit rates; this differs significantly from the literature on this topic, which tends to focus on the financing choices of banks in an environment where the Modigliani-Miller theorem fails (see, for instance, Van den Heuvel (2007)). Section III focuses on the case where capital requirements are not binding and studies the impact of three types of shocks on macroeconomic equilibrium and the degree of cyclicity of lending and interest rates: a negative supply shock, an increase in the central bank’s policy rate, and an increase in the capital adequacy ratio. Considering a range of shocks is important because a regulatory regime may impart a procyclical bias to some variables for certain shocks and a countercyclical bias to the same variables for other shocks. In addition, considering a shock to the policy interest rate allows us to assess how the regulatory regime affects the transmission of monetary policy in the context of a middle-income country—an issue that has not received much attention in the literature. The final section offers some concluding remarks.

## 2 The Model

The model that we develop builds on the static framework with monopolistic banks developed by Agénor and Montiel (2008*a*). Specifically, it combines the cost channel of monetary policy with an explicit analysis of the links between collateral, capital requirements, and bank pricing behavior. Both features capture key aspects of credit market imperfections in middle-income



countries, as documented earlier. Because borrowers' ability to repay is uncertain, lending is collateralized, and effective collateral affects the terms of credit through a risk premium that banks incorporate in lending rates. Moreover, at the prevailing lending rate, the supply of loans is perfectly elastic. There is therefore no endogenous credit rationing, as noted earlier. As is now standard, we also assume that the central bank's supply of liquidity is perfectly elastic at a target interest rate. Monetary policy is therefore implemented through a standing facility. In what follows we describe the behavior of the four types of agents that populate the economy, firms, households, a commercial bank, and the central bank.

## 2.1 Firms

Firms produce a single, homogeneous good. To finance their working capital needs, which consist solely of labor costs, firms (which have no retained earnings, for simplicity) must borrow from the bank. Total production costs faced by the representative firm are thus equal to the wage bill plus the interest payments made on bank loans. For simplicity, we will assume that loans contracted for the purpose of financing working capital (which are short-term in nature), are fully collateralized by the firm's capital stock, and are therefore made at a rate that reflects only the cost of borrowing from the central bank,  $i_R$ .<sup>5</sup> Firms repay working capital loans, with interest, at the end of the period, after goods have been produced and sold. Loans are therefore one-period debt contracts. Profits are transferred at the end of each period to the firms' owners, households.

Let  $W$  denote the nominal wage,  $N$  the quantity of labor employed, and

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<sup>5</sup>Adding a fixed profit margin over and above the refinance rate would not affect the results qualitatively.

$i_R$  the official rate charged by the central bank to the commercial bank (or the refinance rate, for short); the wage bill (inclusive of borrowing costs) is thus  $(1 + i_R)WN$ . The maximization problem faced by the representative firm can be written as

$$N = \arg \max [PY - (1 + i_R)WN], \quad (1)$$

where  $Y$  denotes output and  $P$  the price of the good.

The production function takes the form

$$Y = AN^\alpha K_0^{1-\alpha}, \quad (2)$$

where  $A > 0$  is a shift parameter,  $K_0$  is the beginning-of-period stock of physical capital (which is therefore predetermined), and  $\alpha \in (0, 1)$ .

Solving problem (1) subject to (2), taking  $i_R$ ,  $P$  and  $W$  as given, yields

$$\alpha APN^{\alpha-1}K_0^{1-\alpha} - (1 + i_R)W = 0.$$

This condition yields the demand for labor as

$$N^d = \left[ \frac{\alpha AK_0^{1-\alpha}}{(1 + i_R)(W/P)} \right]^{1/(1-\alpha)}, \quad (3)$$

which can be substituted in (2) to give

$$Y^s \equiv \left[ \frac{\alpha A}{(1 + i_R)(W/P)} \right]^{\alpha/(1-\alpha)} K_0. \quad (4)$$

These equations show that labor demand and supply of the good are inversely related to the effective cost of labor,  $(1 + i_R)(W/P)$ .

Given the short-run nature of the model, the nominal wage is assumed to be rigid at  $\bar{W}$ .<sup>6</sup> This implies, from (3) and (4), that

$$N^d = N^d(P; i_R, A), \quad Y^s = Y^s(P; i_R, A), \quad (5)$$

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<sup>6</sup> Assuming that the nominal wage is indexed to the price level would not alter qualitatively our results as long as indexation is less than perfect.

with  $N_P^d, Y_P^s > 0$ ,  $N_{i_R}^d, Y_{i_R}^s < 0$ , and  $N_A^d, Y_A^s > 0$ .<sup>7</sup> An increase in borrowing costs or a reduction in prices (which raises the real wage) exert a contractionary effect on output and employment.

Real investment is negatively related to the real lending rate:

$$I = h\left(\frac{1 + i_L}{1 + \pi^a}\right), \quad (6)$$

where  $i_L$  is the nominal lending rate,  $\pi^a$  the expected rate of inflation, and  $h' < 0$ .

Using (5) and (6), the total amount of loans demanded (and allocated by the bank) to finance labor costs and capital accumulation,  $L^F$ , is thus

$$L^F = \bar{W}N^d(P; i_R, A) + Ph\left(\frac{1 + i_L}{1 + \pi^a}\right). \quad (7)$$

## 2.2 Households

Households supply labor inelastically, consume goods, and hold two imperfectly substitutable assets: currency (which bears no interest), in nominal quantity  $BILL$ , and bank deposits, in nominal quantity  $D$ . Because households own the bank, they also hold equity capital, which is fixed at  $\bar{E}$ .<sup>8</sup> Household wealth,  $F^H$ , is thus defined as:

$$F^H = BILL^H + D + \bar{E}. \quad (8)$$

The relative demand for currency is assumed to be inversely related to

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<sup>7</sup>Except otherwise indicated, partial derivatives are denoted by corresponding subscripts, whereas the total derivative of a function of a single argument is denoted by a prime.

<sup>8</sup>It could be assumed, as in Cecchetti and Li (2008), that bank capital is directly and positively related to aggregate output, because an increase in that variable raises the value of bank assets—possibly because borrowers are now more able to repay their debts. However, our assumption that  $E$  is fixed is quite reasonable, given the short time frame of the analysis.

its opportunity cost:

$$\frac{BILL^H}{D} = \nu(i_D), \quad (9)$$

where  $i_D$  is the interest rate on bank deposits and  $\nu' < 0$ . Using (8), this equation can be rewritten as

$$\frac{D}{F^H - \bar{E}} = h_D(i_D), \quad (10)$$

where  $h_D(i_D) = 1/[1 + \nu(i_D)]$  and  $h'_D > 0$ . Thus,

$$\frac{BILL^H}{F^H - \bar{E}} = h_B(i_D), \quad (11)$$

where  $h_B = \nu(i_D)/[1 + \nu(i_D)]$  and  $h'_B < 0$ .

Real consumption expenditure by households,  $C$ , depends negatively on the real deposit rate (which captures an intertemporal effect) and positively on labor income and the real value of wealth at the beginning of the period:<sup>9</sup>

$$C = \alpha_0 + \alpha_1 \frac{\bar{W}N}{P} - \alpha_2 \left( \frac{1 + i_D}{1 + \pi^a} \right) + \alpha_3 \left( \frac{F_0^H}{P} \right), \quad (12)$$

where  $\pi^a$  is the exogenous expected inflation rate,  $\alpha_1 \in (0, 1)$  the marginal propensity to consume out of disposable income, and  $\alpha_0, \alpha_2, \alpha_3 > 0$ . The positive effect of current labor income on private spending is consistent with the evidence regarding the pervasiveness of liquidity constraints in middle-income countries (see Agénor and Montiel (2008*b*)) and the (implicit) assumption that households cannot borrow directly from banks to smooth consumption.

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<sup>9</sup>Recall that profits are distributed only at the end of each period. For simplicity, we also assume that interest on deposits is paid at the end of the period; current income consists therefore only of wages.

## 2.3 Commercial Bank

Assets of the commercial bank consist of total credit extended to firms,  $L^F$ , and mandatory reserves held at the central bank,  $RR$ . The bank's liabilities consist of the book value of equity capital,  $\bar{E}$ , household deposits, and borrowing from the central bank,  $L^B$ . The balance sheet of the representative commercial bank can therefore be written as:

$$L^F + RR = \bar{E} + D + L^B, \quad (13)$$

where all variables are measured in nominal terms. Reserves held at the central bank pay no interest and are set in proportion to deposits:

$$RR = \mu D, \quad (14)$$

where  $\mu \in (0, 1)$ .

### 2.3.1 Interest Rate Pricing Rules

The bank is risk-neutral and sets both deposit and lending rates. We consider both decisions in turn.

**Deposit Rate and Capital Buffers** Household deposits and loans from the central bank are viewed as perfect substitutes at the margin; thus, the (gross) interest rate on deposits must be equal to the (gross) cost of central bank liquidity, corrected for the cost of holding reserve requirements on deposits:

$$1 + i_D = (1 + i_R)(1 - \mu). \quad (15)$$

This specification is similar to the one used in Agénor and Montiel (2008). However, we also consider a more general specification, in which the bank's

capital position affects its funding costs, through a “signaling” effect. Specifically, we assume that the bank’s capital buffer (as measured by the ratio of actual to required capital) allows it to raise deposits more cheaply, because households internalize the fact that bank capital increases its incentives to screen and monitor its borrowers. Depositors, therefore, are willing to accept a lower, but safer, return.<sup>10</sup>

Formally, let  $E^R$  be the capital requirement (defined below); the capital buffer, measured as a ratio, is thus  $\bar{E}/E^R$ . The alternative specification that we consider is thus

$$1 + i_D = (1 + i_R)(1 - \mu)f\left(\frac{\bar{E}}{E^R}\right), \quad (16)$$

where  $0 < f(\cdot) \leq 1$ ,  $f' < 0$ , and  $f(1) = 1$ . The last condition implies that if  $\bar{E} = E^R$ , bank capital has no effect on the deposit rate, as specified in (15).<sup>11</sup> The strength of the bank capital channel, as defined here, can therefore be measured by  $|f'|$ . However, from (12), whether the existence of this channel (which operates through the deposit rate) matters depends on the presence of an intertemporal substitution effect on consumption.

An idea similar to ours is developed in Chen (2001), where banks, which act as delegated monitors, must be well-capitalized to convince depositors that they have enough at stake in funding risky projects. Our specification is also consistent with the view, discussed by Calomiris and Wilson (2004), that depositors have a low preference for high-risk deposits and may demand a “lemons premium” (or penalty interest rate) as a result of a perceived

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<sup>10</sup>We could assume that the *absolute* magnitude of equity capital exerts also a signaling effect. However, given that we keep  $\bar{E}$  constant, this modification would not have any substantive implication for our results.

<sup>11</sup>Note that we also assume implicitly that depositors do not observe the risk premium set by the bank; otherwise, if they are risk averse to some degree, a positive relationship could arise between  $\theta_L$  and  $i_D$ .

increase in bank debt risk. To limit this risk (and therefore reduce deposit rates), banks may respond by accumulating capital. Alternatively, the link between the capital buffer and deposit rates could reflect the fact that well-capitalized banks face lower expected bankruptcy costs (that is, lower *ex post* monitoring costs in case of default) and hence lower funding costs *ex ante* from households. Whatever the interpretation, the general point is that in a volatile economic environment, where the risk of adverse shocks is high, signals about a bank’s solvency can have a significant effect on depositors’ behavior—particularly when government deposit guarantees (in the form of a deposit insurance system, for instance) do not exist or are not reliable.<sup>12</sup>

**Lending Rate and the Risk Premium** The contractual lending rate,  $i_L$ , is set as a premium over the central bank refinance rate, which represents the marginal cost of funds:

$$1 + i_L = (1 + \theta_L)(1 + i_R), \quad (17)$$

where  $\theta_L$  is the risk premium. With non-binding capital requirements, we assume that the premium is inversely related to the asset-to-liability ratio of the borrower, given by the “effective” value of collateral pledged by the borrower (that is, assets that can be borrowed against) divided by its liabilities, that is, borrowing for investment purposes,  $PI$ . In turn, the “effective” value of collateral consists of a fraction  $\kappa \in (0, 1)$  of the value of the firm’s nominal output:

$$\theta_L = g\left(\frac{\kappa PY^s}{PI}\right), \quad (18)$$

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<sup>12</sup>Interestingly enough, in the empirical part of their study, Calomiris and Wilson (2004) focus on the behavior of New York City banks during the 1920s and 1930s. They argue that doing so is important because during that time the U.S. deposit insurance system either did not exist or did not have much impact on the risk choices of these banks—therefore allowing them to better assess the link between deposit default risk and bank capital.

where  $g' < 0$ . This specification is consistent with the view that collateral, by increasing borrowers' effort and reducing their incentives to take on excessive risk, reduces moral hazard and raises the repayment probability—inducing the bank therefore to reduce the premium on its loans for investment purposes.<sup>13</sup> Thus, an increase in goods or asset prices, or a reduction in borrowing, tends to raise the firm's effective asset-to-liability ratio and to reduce the risk premium demanded by the bank. As discussed in subsequent sections, the fact that the premium depends endogenously on the price of the domestic good (through its impact on output) allows monetary policy to generate financial accelerator or decelerator effects, implying that the premium may be either procyclical or countercyclical.

### 2.3.2 Capital Requirements

Capital requirements are based on the bank's risk-weighted assets. Suppose that the risk weight on “safe” assets (reserves and loans for working capital needs) is 0, whereas the risk weight on investment loans is  $\sigma > 0$ , respectively. Risk-weighted assets are thus  $\sigma PI$ . The capital requirement constraint can therefore be written as

$$E^R = \sigma \rho PI, \quad (19)$$

where  $\rho \in (0, 1)$  is the capital adequacy ratio (the so-called Cooke ratio). If the penalty (monetary or reputational) cost of holding capital below the required level is prohibitive, we can exclude the case where  $\bar{E} < E^R$ ; the issue is therefore whether  $\bar{E} = E^R$  or  $\bar{E} > E^R$ .

We consider two alternative regimes for the determination of the risk weight  $\sigma$ . Under the first regime, which corresponds to Basel I, the risk

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<sup>13</sup>Note also that (18) is based on flows, rather than stocks, as in Agénor and Montiel (2008). There is therefore no “balance sheet” or “net worth” effect on the premium, as in the Bernanke-Gertler tradition, but rather a (flow) collateral effect.



weight is exogenous at  $\sigma_R$ ; the bank keeps a flat minimum percentage of capital against loans provided for the purpose of investment. Under the second, which corresponds to Basel II, capital requirements are risk-based; the risk weight is endogenous and inversely related to loan quality, which in turn is inversely related to the risk premium imposed by the bank,  $\theta_L$ . This is similar in spirit to linking the risk weight to the probability of default of borrowers, as proposed by Heid (2007). Thus, as allowed under Basel II, we assume that the bank uses an IRB approach, or its own default risk assessment, in calculating the appropriate risk weight—and by implication required regulatory capital. This assumes in turn that the standards embedded in the bank’s risk management system have been validated by the regulator—the central bank here—through an Internal Capital Adequacy Assessment Process (ICAAP).

Formally, the two regimes can be defined as<sup>14</sup>

$$\sigma = \begin{cases} \sigma_R \leq 1 & \text{under Basel I} \\ \sigma(\theta_L), \sigma' > 0 & \text{under Basel II} \end{cases}. \quad (20)$$

Inspection of equations (5), (7), (17), (18), (19), and (20) yields the following result:

**Proposition 1.** *In partial equilibrium, a negative supply shock (a fall in  $A$ ) lowers effective collateral and raises the risk premium on investment loans; under Basel II, the risk weight associated with these loans and capital requirements also increase and bank lending for investment must fall if the capital constraint is binding ( $\bar{E} = E^R$ ).*

The link between  $\sigma$  and  $\theta_L$  under Basel II is consistent with specifications that relate risk weights to the borrower’s probability of default over the business cycle, as for instance in Tanaka (2002) and Heid (2007). Proposition 1 captures one of the general concerns about Basel II: during a recession for

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<sup>14</sup>Under Basel II, it is technically possible for  $\sigma$  to exceed unity.

instance (say, a negative supply shock, as discussed here), if lending to firms is considered riskier because collateral values fall, the bank will be required to hold more capital—or, failing that, to reduce lending (indirectly in the present case, by increasing the risk premium). In turn, the credit crunch will exacerbate the economic downturn, making capital requirements procyclical.

However, in the present setting there are also a number of other (endogenous) factors that will affect the premium. The fall in lending that may result from a binding capital constraint following an increase in risk tends not only to reduce output but also the collateral required by the bank; this dampens the initial increase in the premium. In addition, changes in lending and aggregate supply will affect prices, which will affect the equilibrium value of the premium as well. With the bank capital channel embedded in the model, changes in the capital buffer will also affect the deposit rate and consumption, which in turn will affect aggregate demand and prices. These interactions imply that the net effect of shocks can be fully assessed only through a general equilibrium analysis.

### 2.3.3 Borrowing from the Central Bank

Given that firms' demand for credit determines the actual supply of loans, and that the required reserve ratio is set by the monetary authority, the balance sheet condition (13) can be solved residually for borrowing from the central bank,  $L^B$ . Because there is no reason for the bank to borrow if it can fund its loan operations with deposits, and using (14), we have  $L^B = \max[0, L^F - (1 - \mu)D - \bar{E}]$ .<sup>15</sup>

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<sup>15</sup>Note that in the present setting the bank's profits are not necessarily zero. Just like firms' profits, we assume that this income is distributed to households only at the end of the period.

## 2.4 Central Bank

The balance sheet of the central bank consists, on the asset side, of loans to the commercial bank,  $L^B$ . On the liability side, it consists only of the monetary base,  $MB$ :

$$L^B = MB, \quad (21)$$

with the monetary base given also by the sum of total currency in circulation,  $BILL$ , and reserves:

$$MB = BILL + RR. \quad (22)$$

Monetary policy is operated by setting the refinance rate at the constant rate  $i_R$  and providing liquidity (at the discretion of the commercial bank) through a standing facility.

Because central bank liquidity is endogenous, the monetary base is also endogenous; this implies, using (14) and (21), that the supply of currency is

$$BILL^s = L^B - \mu D. \quad (23)$$

## 2.5 Market-Clearing Conditions

There are five market equilibrium conditions to consider: four financial (deposits, loans, central bank credit, and cash), and one for the goods market. Markets for deposits and loans adjust through quantities, with the bank setting prices in both cases. The supply of central bank credit is perfectly elastic at the official refinance rate  $i_R$  and the market also equilibrates through quantity adjustment.

The equilibrium condition of the goods market, which determines the goods price  $P$ , is given by:

$$Y^s = C + I. \quad (24)$$

The last equilibrium condition relates to the market for cash, and (under the assumption that the counterpart to bank loans is held by firms in the form of currency) involves (11) and (23). However, there is no need to write this condition explicitly, given that by Walras' Law it can be eliminated.

### 3 Non-Binding Capital Requirements

We first consider the case where existing equity capital is higher than the required value, that is,  $\bar{E} > E^R$ , regardless of whether  $\sigma$  is endogenous or not. This is consistent with the evidence suggesting that, in normal times, banks often hold more capital than the regulatory minimum—possibly as a result of market discipline (see Rochet (2008)). However, although bank capital is not a binding constraint on the bank's behavior, it still plays an indirect role, by affecting how the bank sets the deposit rate.<sup>16</sup>

The solution of the model is described in the Appendix. As shown there, the model can be condensed into two equilibrium conditions in terms of the risk premium,  $\theta_L$ , and the price of the domestic good,  $P$ . The first is the financial equilibrium condition, defined by (18). The second is the goods market equilibrium condition (24), after substitution from (5), (6), (12), (16), (17), and (20).

A graphical presentation of the equilibrium is shown in Figure 1. In the northeast quadrant of the figure, the financial equilibrium curve is labeled  $FF$ . As shown in the Appendix,  $FF$  does not depend on the regulatory regime; its slope is given by

$$\left. \frac{d\theta_L}{dP} \right|_{I,II}^{NB,FF} = \frac{g'}{\Sigma} \left( \frac{\kappa Y_P^s}{h} \right) < 0,$$

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<sup>16</sup>Equivalently, the condition  $\bar{E} > E^R$  sets an upper bound on investment,  $PI < \bar{E}/\sigma\rho$ . We will assume that this restriction is not binding.

where  $NB$  stands for “nonbinding” and  $\Sigma > 0$  is defined in the Appendix. Intuitively, a rise in prices stimulates output and increases the effective value of firms’ collateral relative to the initial demand for loans; the risk premium must therefore fall, at the initial level of investment.

The goods market equilibrium condition yields the curves labeled  $G^1G^1$  (which corresponds to the Basel I regime) and  $G^2G^2$  (corresponding to the Basel II regime). The slopes of these curves are given by, respectively

$$\left. \frac{d\theta_L}{dP} \right|_I^{NB,GG} = \frac{1}{\Delta_1} \left\{ Y_P^s + \frac{\alpha_1}{P^2} (N^d - P N_P^d) - \alpha_2 (1 + i_R) f' \frac{\bar{E}}{\sigma_R \rho P^2 h} + \alpha_3 \left( \frac{F_0^H}{P^2} \right) \right\}, \quad (25)$$

where  $\Delta_1 < 0$  if  $\alpha_2$  is not too large (see the Appendix) and, with  $\sigma(\theta_L) = \sigma_R$  initially,

$$\left. \frac{d\theta_L}{dP} \right|_{II}^{NB,GG} = \left( \frac{\Delta_1}{\Delta_2} \right) \left. \frac{d\theta_L}{dP} \right|_I^{NB,GG}, \quad (26)$$

where  $\Delta_2 < 0$  and  $|\Delta_2| > |\Delta_1|$ . Thus, a comparison of (25) and (26) implies that  $G^2G^2$  is flatter than  $G^1G^1$ . Inspection of these results also shows that curves  $G^1G^1$  and  $G^2G^2$  have a steeper slope than in the absence of a bank capital channel ( $f' = 0$ ), given by

$$\left. \frac{d\theta_L}{dP} \right|^{GG} = \frac{1}{(1 + i_R)h'} \left\{ Y_P^s + \frac{\alpha_1}{P^2} (N^d - P N_P^d) + \alpha_3 \left( \frac{F_0^H}{P^2} \right) \right\},$$

which is the slope of curve  $GG$  in Figure 1.

Intuitively, the negative slope of the  $GG$  curves can be explained as follows. A rise in prices tends to lower aggregate demand through a negative wealth effect on consumption. At the same time, it increases the nominal value of loans and thus capital requirements; the fall in the capital buffer raises the deposit rate, which (through intertemporal substitution) lowers current consumption. However, the increase in  $P$  also boosts aggregate supply, by reducing the real (effective) wage, and may stimulate consumption,

as a result of higher labor demand and distributed wage income.<sup>17</sup> Because the shift in supply outweighs the wage income effect, and because the wealth and capital buffer effects are unambiguously negative, an increase in prices creates excess supply. The risk premium must therefore fall to stimulate investment and restore equilibrium in the goods market. This implies that the  $GG$  curves have a negative slope, as shown in the figure.

Curves  $G^1G^1$  and  $G^2G^2$  are steeper than curve  $GG$  (which corresponds to  $f' = 0$ ) because the bank capital channel adds additional downward pressure on consumption—requiring therefore a larger fall in the premium to generate an offsetting expansion in investment.

By implication, the intuitive reason why  $G^2G^2$  is flatter than  $G^1G^1$  is because under Basel II there is an additional effect—the fall in the risk premium alluded to earlier lowers the risk weight. This mitigates therefore the initial drop in the capital buffer (at the initial level of investment) induced by the rise in prices. In turn, this dampens the increase in the deposit rate and the drop in consumption. Given that aggregate supply and wage income increases in the same proportion in both regimes, the risk premium must fall by *less* under Basel II to stimulate investment and reestablish equilibrium between supply and demand.

Under standard dynamic assumptions, local stability requires the  $GG$  curves to be steeper than  $FF$ .<sup>18</sup> The positive relationship between the risk premium and the lending rate is shown in the northwest quadrant, whereas the negative relationship between the lending rate and investment is dis-

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<sup>17</sup>The net effect of distributed wage income on consumption depends on the sign of  $PN_P^d - N^d$ . Thus, a positive effect requires that  $PN_P^d/N^d > 1$ , or equivalently that the elasticity of labor demand with respect to prices be sufficiently high.

<sup>18</sup>Local stability can be analyzed by postulating an adjustment mechanism that relates changes in  $P$  to excess demand for goods, and changes in the risk premium to the difference between the its equilibrium and current values; see Agénor and Montiel (2008a).

played in the northwest quadrant. The supply of goods, which is an increasing function of the price level, is shown in the southeast quadrant. The difference between supply and investment in the southwest quadrant gives private spending,  $C$ . The economy's equilibrium is determined at points  $E$ ,  $D$ ,  $H$ , and  $J$ .<sup>19</sup>

We now turn to an analysis of the adjustment process to a supply shock, a change in the refinance rate, and a change in the capital adequacy ratio.

### 3.1 Negative Supply Shock

Consider first a negative shock to output, that is, a drop in  $A$ .<sup>20</sup> The results are illustrated in Figure 2; because the difference between the two regulatory regimes is only in terms of the slope of curve  $GG$ , we consider only the Basel I regime, to avoid cluttering the graph unnecessarily. Differences between the two regimes are pointed out later. We also focus at first on the movement that leads to point  $E'$ .

The first effect of the shock is of course a drop in output; as shown in the southeast quadrant, the supply curve shifts inward, with output (at the initial level of prices) dropping from  $H$  to  $M$ . The drop in output lowers the value of collateral at the initial level of investment; the premium must therefore increase to account for the fact that lending has now become more risky. Curve  $FF$  therefore shifts upward, and  $\theta_L$  rises first from  $E$  to  $B$ . The fall in output also leads to excess demand on the goods market; at initial prices, the risk premium must therefore increase to restore equilibrium (by

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<sup>19</sup>Of course,  $GG$ ,  $G^1G^1$ , and  $G^2G^2$  would not normally intersect  $FF$  at the same point  $E$ . This is shown only for convenience.

<sup>20</sup>Instead of a supply shock, we could also consider a negative demand shock, as measured by a fall in  $\alpha_0$  in (12). Although the transmission mechanism is different, the conclusion about the procyclicality of Basel I and Basel II in this case are qualitatively similar to those discussed below. We therefore do not report them to save space.

lowering investment). Curve  $G^1G^1$  therefore shifts also upward.

There is, however, “overshooting” in the behavior of the premium; the initial increase in not sufficient to eliminate excess demand through a drop in investment only—to do so would require an increase from  $E$  to  $B''$ , which is not feasible. Accordingly, prices must increase, which tend (through a negative wealth effect) to lower consumption as well. Because the increase in prices also lowers real wages, the initial drop in output is dampened; after falling from  $H$  to  $M$ , output recovers gradually from  $M$  to  $H'$ . The associated increase in the value of collateral allows the premium to fall, from  $B$  to the new equilibrium point,  $E'$ . In the new equilibrium, the lending rate is higher, investment lower, and so is consumption.

However, it is also possible for the new equilibrium to be characterized by a *lower* premium and higher prices; this is illustrated by the curves intersecting at point  $E'''$  in Figure 2. This corresponds to a case where curve  $FF$  shifts only slightly (which occurs if the risk premium does not adjust rapidly to changes in the collateral-loan ratio, that is,  $g'$  is small) and  $G^1G^1$  shifts by a large amount (which occurs if investment is not very sensitive to the lending rate).<sup>21</sup> Following an upward jump (from  $E$  to  $B'$ ), the premium undergoes a prolonged “decelerator” effect, eventually with a smaller adverse effect on investment, but at the cost of higher prices.<sup>22</sup>

How does the “capital channel” operate in this setting? Because investment falls, capital requirements also fall. This implies that the bank’s capital

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<sup>21</sup>If the premium does not adjust at all following a drop in  $A$ —so that  $FF$  remains at its initial position—the new equilibrium point would be at  $E''$ . The case where  $FF$  does not change would occur if, for instance, effective collateral was measured, as in Agénor and Montiel (2008a), in terms of the value of the beginning-of-period capital stock,  $PK_0$ .

<sup>22</sup>Although not represented in Figure 2, it is also possible for the equilibrium outcome to entail a *rise* in the premium and a *fall* in prices (that is, an equilibrium point located to the northwest of  $E$ ). This would occur if  $FF$  shifts by a large amount and  $G^1G^1$  shifts only a little.



buffer increases. Through the signaling effect discussed earlier ( $f' < 0$ ), the deposit rate falls; this, in turn, tends to increase consumption today, through intertemporal substitution. This result can be summarized as follows:

**Proposition 2.** *With non-binding capital requirements, the bank capital channel induces an expansion of consumption in response to a negative supply shock.*

Put differently, although bank capital has no direct effect on loans, it does have indirect effects, to the extent that it affects deposit rates, aggregate demand, and thus prices—which in turn affect output, collateral, and the risk premium. This transmission channel is similar under both regulatory regimes—except that with Basel II the effect on price are magnified and the effect on the risk premium is mitigated.

More formally, consider the following definition:<sup>23</sup>

**Definition.** *A variable  $x$  is procyclical (countercyclical) with respect to an exogenous shock  $z$  if its movement in response to  $z$ , as measured by the first derivative  $dx/dz$ , is such as to amplify (mitigate) the movement in equilibrium output in response to that shock,  $dY/dz$ .*

In the present setting, we can focus on the risk premium, given that the supply of loans is perfectly elastic, and that the demand for credit for the purpose of financing working capital needs is (by definition) procyclical.<sup>24</sup> Here, we have  $d\theta_L/dA \leq 0$ , which implies that the risk premium can be either procyclical with respect to  $A$ —falling during booms and rising during downswings, thereby exacerbating the initial movement in output, as per the definition above—or countercyclical ( $d\theta_L/dA > 0$ ). This ambiguity exists

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<sup>23</sup>Borio and Zhu (2008) for instance use a definition that is essentially similar. Note that, in the literature, procyclicality is often defined in terms of required capital only.

<sup>24</sup>Note that the cyclicity of the *nominal* value of loans for investment purposes,  $PI$ , depends on the behavior of prices as well. Our focus on the risk premium is equivalent to focusing on *real* lending for investment, given that these two variables always vary in opposite directions.

regardless of the regulatory regime, because it holds even in the absence of a bank capital channel ( $f' = 0$  or  $\alpha_2 = 0$ )—given that in this case neither  $FF$ , nor  $GG$ , depends on  $\sigma$ .

In the case where  $f' > 0$  (and  $\alpha_2 > 0$ ), the impact of the regulatory regime on the degree of procyclicality of the risk premium can be formally assessed by calculating the derivative of the equilibrium outcome  $d\theta_L/dA$  with respect to  $\sigma$ , that is,  $d^2\theta_L/dAd\sigma$ , in a manner similar to Heid (2007). More intuitively, this outcome can be gauged by examining how  $\sigma$  affects the slopes of  $FF$  and  $GG$ . As noted earlier,  $FF$  does not depend on  $\sigma$ ;  $G^2G^2$  is flatter than  $G^1G^1$ ; and both  $G^1G^1$  and  $G^2G^2$  have a steeper slope with  $f' > 0$  than with  $f' = 0$ . This leads to the following proposition:

**Proposition 3.** *With non-binding capital requirements, and a bank capital channel, both regulatory regimes magnify the procyclical effect of a negative supply shock on the risk premium; all else equal, Basel II is less procyclical than Basel I.*

Intuitively, the reason why the regulatory capital regime magnifies an upward movement in the risk premium compared to the case where the regime does not matter ( $f' = 0$ ) is because the improvement in the capital buffer tends (as noted in Proposition 2) to stimulate private consumption; consequently, at the initial level of prices, “bringing down” aggregate demand to the lower level of output requires a larger drop in investment—and therefore a larger increase in the premium. This movement is also more significant in the Basel I regime, because in the case of Basel II the initial increase in the premium raises the risk weight—which in turn limits the downward effect on capital requirements resulting from the fall in the level of investment (that is,  $E^R$  falls by less than the drop in  $I$  because  $\sigma$  rises); as a result, the increase in the capital buffer is less significant, the deposit rate falls by less, and the stimulus to consumption is mitigated. The rise in the risk premium required

to restore equilibrium to the goods market is thus of a lower magnitude.

### 3.2 Increase in Official Refinance Rate

The macroeconomic effects of an increase in the refinance rate are illustrated in Figure 3. The immediate effect of an increase in  $i_R$  is twofold. First, it raises production costs and lowers output, which drops from point  $H$  to  $M$  in the southeast quadrant, following an inward shift in the supply curve. The resulting drop in effective collateral tends to put upward pressure on the risk premium. Second, there is a direct effect on the lending rate; because an increase in the refinance rate raises the cost of marginal funds, it is “passed on” directly to borrowers. In the northeast quadrant, the curve linking  $\theta_L$  and  $i_L$  shifts outward. The increase in the lending rate lowers investment, which in turn tends to lower the risk premium by reducing the volume of bank loans. The net impact effect on the premium is thus ambiguous. We assume in what follows that the net effect of an increase in  $i_R$  is to raise the premium. As formally established in the Appendix, this requires that the elasticity of output with respect to the refinance rate be higher (in absolute terms) than the elasticity of investment with respect to that rate. The “collateral” effect therefore dominates the “loan demand” effect.<sup>25</sup> If so, then, curve  $FF$  shifts upward and the premium jumps from point  $E$  to point  $B$ .

On the goods market, there are several effects at play at the initial level of prices. As noted earlier, both aggregate supply and investment fall. In addition, consumption changes as well, as a result of two effects. On the one hand, the refinance rate raises directly the deposit rate, thereby lowering consumption as a result of the standard intertemporal effect. On the other,

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<sup>25</sup>This is quite appropriate for middle-income countries where bank loans are essential for short-term economic activity.

the fall in investment reduces capital requirements, thereby increasing the capital buffer, which in turn tends to lower the deposit rate and stimulate consumption. The net effect on consumption is thus ambiguous in general. We assume in what follows that the net effect on aggregate demand is negative; a sufficient (although not necessary) condition for that to occur is for the direct cost effect of  $i_R$  on  $i_D$  to dominate the indirect capital buffer effect. Because aggregate supply and aggregate demand both fall, prices may either increase or fall to restore equilibrium in the goods market. Graphically, curve  $G^1G^1$  may shift either left or right. If excess demand (supply) prevails at the initial level of prices, the price level must increase (fall) and  $G^1G^1$  shifts to the left (right).

Thus, following its initial jump from  $E$  to  $B$ , the risk premium can either continue increasing, from  $B$  to  $E'$ , or fall from  $B$  to  $E''$ . In the first case, there is a financial accelerator effect; the drop in prices stimulates consumption (through the wealth effect), raises real wages and lowers output (which falls from  $M$  to  $H'$ ), and the fall in collateral tends to increase the premium—despite the drop in the demand for loans. In the second case, the increase in prices tends to stimulate output and to raise the effective value of collateral while reducing consumption; there is therefore a financial “decelerator” effect.<sup>26</sup>

Again, what is the role of the regulatory capital regime? The capital buffer effect mitigates the drop in consumption (as before) and reinforces the possibility that aggregate demand falls by less than supply—and therefore increases the likelihood of a drop in prices and the occurrence of a financial

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<sup>26</sup>Note also that even if  $G^2G^2$  does not shift—which is the case if  $\alpha_2 = 0$ —there would still be a financial accelerator effect (this time from  $B$  to  $C$ , the new equilibrium), but the financial decelerator effect cannot emerge. The reason is that excess demand cannot occur in that case.

accelerator effect. Thus, even if capital requirements are not binding, they do affect the transmission process of monetary policy. Indeed, the bank capital channel, as modeled here, may enhance the effectiveness of a contractionary monetary policy—in contrast to some of the predictions in the literature (see, for instance, Tanaka (2002)). Moreover, under the Basel II regime, the effects described above operate in similar fashion. But because  $G^2G^2$  is less steep than  $G^1G^1$ , price effects are magnified, whereas changes in the premium are mitigated. Moreover, from Proposition 2, both of these curves are steeper than curve  $GG$  with  $f' = 0$ . We therefore have the following result:

**Proposition 4.** *With non-binding capital requirements, and under either regulatory regime, the bank capital channel magnifies the impact of an increase in the central bank refinance rate on the risk premium and mitigates its impact on prices, compared to the case where it does not exist. In addition, the Basel II regime imparts less procyclicality to the risk premium compared to the Basel I regime.*

### 3.3 Increase in Capital Adequacy Ratio

The effects of an increase in the capital adequacy ratio are illustrated in Figure 4. Curve  $FF$  does not change, given that the financial equilibrium condition does not depend directly on that ratio. the increase in  $\rho$  increases capital requirements and lowers the capital buffer. The cost of deposits therefore increases, which tends to lower consumption as households engage in intertemporal substitution. At the initial level of the risk premium, prices must fall to stimulate consumption (through the wealth effect) and eliminate the excess supply of goods. Curve  $GG$  therefore shifts downward (or to the left), and prices fall from  $E$  to  $B$ . In turn, the fall in prices raises the real wage and leads to a contraction in output, from  $H$  to  $M$ . Because the fall in output lowers the value of collateral, the risk premium starts rising, from  $E$

to  $E'$ , while output continues to drop, from  $M$  to  $H'$ . During the transition period, prices decline continuously. The new equilibrium point is located at  $E'$ , characterized by a higher lending rate, lowers prices, a lower level of investment, and lower output.

Thus, tighter capital regulation reduces bank leverage while at the same time increasing the cost of (market) funding for the bank and the cost of borrowing for firms. The fact that an increase in the capital adequacy ratio leads to a higher equilibrium loan rate and reduced lending is consistent with the prediction of various other models based on very different premises (see VanHoose (2007)). Of course, if the bank capital channel is not present ( $f' = 0$ ), curve  $GG$  would not shift and a change in  $\rho$  would have no effect on output and prices as long as  $\bar{E} > \sigma\rho L^F$ .<sup>27</sup>

## 4 Binding Capital Requirements

We now consider the case where the capital requirement constraint (19) is continuously binding, that is,  $\bar{E} = \sigma\rho L^F$ . Because equity is predetermined, bank lending must adjust to satisfy the capital requirement:

$$L^F = PI = \bar{E}/\sigma\rho, \quad (27)$$

regardless of whether  $\sigma$  is endogenous or not.<sup>28</sup> We assume that constraint (27) is continuously binding, due possibly to heavy penalties or reputational costs associated with default on regulatory requirements, as noted earlier.

With (27) determining investment, equation (6) is now solved for the

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<sup>27</sup>Of course, this also depends on the assumption  $\alpha_2 > 0$ .

<sup>28</sup>If  $\sigma_R = 1$ , the capital adequacy requirement is a leverage ratio, which restricts on-balance-sheet assets to a simple multiple of available capital ( $L^F = \bar{E}/\rho$ ). Note also that because the bank holds no other risky assets in its portfolio, it cannot engage in regulatory arbitrage.

lending rate:

$$1 + i_L = h^{-1}\left(\frac{\bar{E}}{P\sigma\rho}\right), \quad (28)$$

where  $\pi^a = 0$  for simplicity. The interest rate-setting condition (17) is now used to solve for the risk premium:

$$\theta_L = \left(\frac{1 + i_L}{1 + i_R}\right) - 1 = \left(\frac{1}{1 + i_R}\right)h^{-1}\left(\frac{\bar{E}}{P\sigma\rho}\right) - 1. \quad (29)$$

Collateral therefore plays no longer a direct role in determining the risk premium; equation (18) serves now to determine the effective collateral required, that is, coefficient  $\kappa$ . Of course, for the solution to be feasible requires  $\kappa < 1$ , which we assume is always satisfied. Thus, we continue to assume that credit rationing does not emerge.

With a binding capital requirement, the capital buffer is unity, and because  $f(1) = 1$ , the deposit rate-setting condition is (15). Thus, the bank capital channel, as identified in the previous section, does not operate. However, the adjustment process to shocks continues to depend in important ways on the regulatory regime; for clarity, we consider them separately.

## 4.1 Constant Risk Weights

Macroeconomic equilibrium Under the Basel I regime is now illustrated in Figure 5. As before, the southeast quadrant shows the positive relationship between output and prices. From (27), and with  $\sigma$  constant at  $\sigma_R$ , investment and prices are inversely related, as shown in the southwest quadrant. Equations (28) and (29) also imply a negative relationship between investment and the risk premium, as displayed in the northwest quadrant. Because both the risk weight and investment are independent of the risk premium, the goods market equilibrium condition, shown as curve  $G^3G^3$  in the northeast

quadrant, is vertical. The financial equilibrium condition, shown as curve  $F^3F^3$ , has now a positive slope, given by (see the Appendix):

$$\left. \frac{d\theta_L}{dP} \right|_I^{B,FF} = -\left(\frac{1}{1+i_R}\right)h^{-1'}\left(\frac{\bar{E}}{P^2\sigma_R\rho}\right) > 0, \quad (30)$$

where  $B$  stands for “binding.”

Intuitively, the reason why  $FF$  is positively sloped is because higher prices now reduce real investment (as implied by (27)), which in turn can only occur if the premium increases. The equilibrium obtains at points  $E$ ,  $H$ ,  $J$ , and  $D$ . Graphically,  $F^3F^3$  is steeper the larger  $\sigma_R$  is, so that  $\partial[\frac{d\theta_L}{dP}|_I^{B,FF}]/\partial\sigma_R > 0$ . All else equal, the higher  $\sigma_R$  is, the larger the effect of any shock that leads to a shift in the financial equilibrium condition on the risk premium, and the smaller the effect on prices.

Figures 6, 7, and 8 illustrate the macroeconomic effects of the same three shocks analyzed earlier. A negative supply shock leads to an inward shift of the supply curve (as before), but this has no direct effect on the premium at the initial level of prices, in contrast to the case of nonbinding requirements. Thus,  $F^3F^3$  does not shift. Excess demand of goods requires an increase in prices to clear the market and  $G^3G^3$  shifts to the right. The increase in prices lowers investment, and this must be accompanied by an increase in the risk premium. The price hike also lowers consumption, through a negative wealth effect. Thus, the adjustment to a negative supply shock entails both an increase in prices and a reduction in aggregate demand. The new equilibrium position is at points  $E'$ ,  $H'$ ,  $J'$ , and  $D'$ . The risk premium is thus unambiguously procyclical ( $d\theta_L/dA < 0$ ).

To analyze the role of the capital regime in the transmission process of this shock, recall that with a binding requirement the deposit rate-setting condition (16) becomes independent of the capital buffer. However, as can



be inferred from (27), the higher the risk weight (and the capital adequacy ratio), the larger the drop in investment and lending; the smaller therefore the adjustment in prices required to equilibrate supply and demand. Thus, the “capital channel” operates now through investment, rather than consumption. At the same time, however, a larger drop in investment must be accompanied by a larger increase in the risk premium. Formally, it can be shown that the general equilibrium effect is  $|d^2\theta_L/dAd\sigma_R| > 0$ .

The effects of an increase in the refinance rate are illustrated in Figure 7. For the reasons discussed in the previous section, the goods market equilibrium condition can move either left or right, depending on whether excess demand or supply prevails at the initial level of prices. However, for  $P$  given, the increase in the refinance rate must now be accompanied by a *fall* in the risk premium, in contrast to the nonbinding case, to keep investment at its initial level. The curve linking  $I$  and  $\theta_L$  in the northwest quadrant shifts inward, and the premium drops from  $E$  to  $B$  (or equivalently from  $D$  to  $L$ ). If excess demand prevails initially, prices must increase to restore equilibrium, and curve  $G^3G^3$  must shift to the right; after its initial drop, the risk premium begins to rise, to validate the drop in investment. By contrast, if there is excess supply initially, prices must fall, thereby increasing investment and consumption (the latter through the wealth effect) and curtailing aggregate supply. The risk premium adjusts gradually downward from  $B$  to  $E''$  to validate the increase in investment. As can be inferred from (27), if prices fall, and given that  $\sigma$  is constant at  $\sigma_R$ , investment *always* increases in equilibrium (from  $J$  to  $J''$ ). The larger  $\sigma_R$  is, the smaller this increase (or the larger the fall, if prices rise). The regulatory regime therefore magnifies changes in the risk premium ( $|d^2\theta_L/di_Rd\sigma_R| > 0$ ).

Figure 8 shows the impact of an increase in the capital adequacy ratio.

The immediate effect, as can be inferred from (27), is a reduction in investment at the initial level of prices; the curve in the southwest quadrant shifts inward. Investment drops from  $J$  to  $L$ , and this must be accompanied by an upward jump in the premium, from  $E$  to point  $B$ , located on the new  $F^3F^3$  curve positioned to the left of the original curve. Because of the incipient excess supply, prices must fall; thus, curve  $G^3G^3$  also shifts to the left. The drop in prices mitigates the initial drop in investment, which recovers from  $L$  to  $J'$ . Although output (and thus collateral) falls during the transition, the gradual increase in investment must be associated with a drop in the risk premium, from  $B$  to  $E'$ . At  $E'$ , the risk premium is higher than in the initial equilibrium; however, if the shift in  $F^3F^3$  is not large, the end result may be a *fall* in the risk premium (point  $E''$ ). In either case, prices always fall, as in the nonbinding case (Figure 4). Again, regardless of the direction of the effect, the larger  $\sigma_R$  is, the larger the equilibrium change in the risk premium ( $|d^2\theta_L/dpd\sigma_R| > 0$ ).

The results of these experiments can be summarized in the following proposition:

**Proposition 5.** *With binding capital requirements, and under Basel I, a negative supply shock is unambiguously procyclical, whereas an increase in the refinance rate or the capital adequacy ratio may be either procyclical or countercyclical. The higher the risk weight  $\sigma_R$  is, the stronger the effect of all these shocks on the risk premium.*

## 4.2 Endogenous Risk Weights

Under the Basel II regime, the endogeneity of  $\sigma$  precludes the use of a four-quadrant diagram to illustrate the determination of equilibrium; it is now shown in a single quadrant, in Figure 9. The determination of the financial equilibrium condition  $F^4F^4$  follows the same logic as before; it therefore has

a positive slope, given now by (see the Appendix):

$$\left. \frac{d\theta_L}{dP} \right|_{II}^{B,FF} = -\frac{1}{\Sigma_4} \left( \frac{1}{1+i_R} \right) h^{-1'} \left( \frac{\bar{E}}{P^2 \sigma_R \rho} \right) > 0, \quad (31)$$

where  $\Sigma_4 > 0$  if  $\sigma'$  is not too large, and  $|\Sigma_4| < 1$ . A comparison of (30) and (31) shows that this slope is *steeper* than under Basel I. Intuitively, the reason is that now the direct, positive effect of an increase in prices on the premium (which validates the fall in real investment, as noted earlier), is compounded by an increase in the risk weight. Thus, all else equal, shocks would now tend to have larger effects on the risk premium, and more muted effects on prices, than under the previous regime.

The goods market equilibrium condition, however, is no longer vertical; because  $\sigma$  depends on  $\theta_L$ , it can be displayed as a negative relationship between the risk premium and the price level, denoted  $G^4 G^4$  in Figure 9, with slope

$$\left. \frac{d\theta_L}{dP} \right|_{II}^{B,GG} = \frac{1}{\Delta_4} \left\{ Y_P^s + \frac{\alpha_1}{P^2} (N^d - P N_P^d) + \alpha_3 \left( \frac{F_0^H}{P^2} \right) + \frac{\bar{E}}{P^2 \sigma_R \rho} \right\}, \quad (32)$$

where  $\Delta_4 < 0$ .

The reason why  $GG$  is downward-sloping is now different from the non-binding case: here an increase in the price level lowers real investment, as implied by the binding constraint (27); this must be validated by an *increase* in the risk premium. However, the price increase also lowers consumption and stimulates output (for reasons outlined earlier); in turn, this requires a *fall* in the risk premium to stimulate investment and restore equilibrium between supply and demand. The figure assumes that the second effect dominates the first (or equivalently that  $\sigma'$  is not too large), so  $G^4 G^4$  has indeed a negative slope. Thus, the goods market equilibrium condition is now *less steep*; all else equal, shocks would tend to have more muted effects on the

risk premium, and larger effects on prices, than under Basel I. Because the slopes of the two curves are affected in opposite direction by a switch from Basel I to Basel II, it cannot be ascertained *a priori* whether shocks would tend to have larger effects on the risk premium, as under the nonbinding case—where only  $GG$  was affected by a switch in regime.

Figure 10 illustrates the impact of a negative supply shock; curve  $G^4G^4$  shifts to the right and the equilibrium is characterized by a higher risk premium and higher prices, as in Figure 6. Thus, the shock is procyclical, as under Basel I. But even though only the  $GG$  curve shifts (as is the case under Basel I), the initial position of  $FF$  matters for the final outcome. Thus, whether Basel II is more procyclical or less procyclical than Basel I cannot be determined unambiguously.

The impact of an increase in the refinance rate is illustrated in Figure 11. Because  $G^4G^4$  can move either left or right, a range of outcomes is possible—just like under the nonbinding case (Figure 3) and the Basel I regime under the binding case (Figure 7). Whether a change in the risk premium is procyclical or not cannot therefore be ascertained *a priori*. Finally, Figure 12 shows the effects of an increase in the capital adequacy ratio. Both  $G^4G^4$  and  $F^4F^4$  shift to the left. Although prices fall unambiguously, as before, the risk premium can either fall (point  $E'$ ) or increase (point  $E''$ ), depending on the magnitude of the shift in  $F^4F^4$ , as with Basel I (see Figure 8). Thus, whether the increase in the capital adequacy ratio is procyclical or countercyclical is again ambiguous.

The following proposition summarizes the results of these experiments:

**Proposition 6.** *With binding capital requirements, and under Basel II, a negative supply shock is unambiguously procyclical; an increase in the refinance rate or the capital adequacy ratio may be either procyclical or countercyclical. Whether these shocks entail more procyclicality (with respect to*

*Basel I) in the risk premium cannot be ascertained a priori.*

## 5 Concluding Remarks

The purpose of this paper has been to analyze the procyclical effects of Basel I- and Basel II-type capital standards in a simple model that captures some of the most salient credit market imperfections that characterize middle-income countries. In our model, capital requirements are essentially aimed at influencing bank decision-making regarding exposure to loan default. They affect both the quantity of bank lending and the pricing of bank deposits. The bank cannot raise additional equity capital—a quite reasonable assumption for a short-term horizon. The deposit rate is sensitive to the size of the buffer, through a signaling effect. Well-capitalized banks face lower expected bankruptcy costs and hence lower funding costs from the public. We also establish a link between regulatory risk weights and the bank’s risk premium under Basel II; this is consistent with the fact that in that regime the amount of capital that the bank must hold is determined not only by the institutional nature of its borrowers (as in Basel I), but also by the riskiness of each particular borrower. Thus, capital adequacy requirements affect not only the *levels* of bank lending rates, and thus investment and output; they also affect the *sensitivity* of bank rates (through the risk premium) to changes in output and prices.

Our analysis showed that different types of bank capital regulations affect in different ways the transmission process of exogenous shocks to bank interest rates, prices, and economic activity. As discussed in the existing literature, and regardless of the regulatory regime, capital requirements can have sizable real effects if they are binding, because in order to satisfy them

banks may need to curtail lending through hikes in interest rates. However, we also showed that, even if capital requirements are not binding, a “bank capital channel” may operate through a signaling effect of capital buffers on deposit rates. If there is some degree of intertemporal substitution in consumption, this channel may generate significant effects on the real economy.

Several policy lessons can be drawn from our analysis. First, regulators should pay careful attention to the impact of risk weights on bank portfolio behavior when they implement regulations. Second, capital buffers may not actually mitigate the cyclical effects of bank regulation; in our model, capital buffers, by lowering deposit rates, are actually expansionary. Thus, if capital buffers are increased during an expansion, with the initial objective of being *countercyclical*, they may actually turn out to be *procyclical*. This is an important conclusion, given the prevailing view that counter-cyclical regulatory requirements may be a way to reduce the buildup of systemic risks: if the signaling effects of capital buffers are important, “leaning against the wind” may not reduce the amplitude of the financial-business cycle.<sup>29</sup> A more detailed study of the empirical importance of these signaling effects is thus a pressing task for middle-income countries. Moreover, the possibility of *asymmetric effects* should also be explored; for instance, a high capital buffer in good times may lead households (as owners of banks) to put pressure on these banks to generate more profits, in order to guarantee a “minimum” return on equity; by contrast, the signaling effect alluded to earlier may be strengthened in bad times.

Our analysis can be extended in several directions. One of them could be

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<sup>29</sup>There are also other problems associated with “forward-looking provisioning” or “buffer stock approach,” as advocated by some—including the issue of coordination and roles of prudential policies and accounting rules, and the fact that if countercyclical constraints were to be applied to banks, regulatory arbitrage may encourage market funding to step in, thereby inducing risks to migrate elsewhere in the financial system.

to extend the bank capital channel as modeled here by assuming that a large capital buffer induces banks not only to reduce deposit rates as discussed earlier but also to engage in more risky behavior, which may lead them to relax lending standards and lower the cost of borrowing, in order to stimulate the demand for loans and increase profits. However, because this would lead to an expansionary effect on investment, it would go in the same direction as the consumption effect alluded to earlier. Thus, our results would not be affected qualitatively.

A second direction would be to examine the links between capital requirements and risk taking. If capital requirements reduce incentives for risk taking by banks (as in Rochet (1992) and Repullo and Suarez (2008)), we should have more collateralized lending; this could lead in the present model to a positive link between the reserve adequacy ratio,  $\rho$ , and the collateral parameter,  $\kappa$ . However, at the same time this could increase volatility in the risk premium, and thus the amplitude of macroeconomic fluctuations.

A third direction would be to embed the financial features of the present model in a dynamic optimizing framework, as for instance in Markovic (2006), Meh and Moran (2008), and Aguiar and Drumond (2007). This would allow one to account for the fact that, in practice, banks can and do issue stocks, hybrid debt capital instruments, and subordinated term debt instruments.<sup>30</sup> These will certainly alleviate the impact of the regulation on bank asset and liability management. In a dynamic perspective, capital requirement may also depend on the *growth rate* of assets; this would help banks to strengthen buffers in good times. In a dynamic setting, where equity is endogenous, there is also a possibility that the capital requirement can limit the bank's ability

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<sup>30</sup>The use of a model with proper micro foundations instead of postulated behavioral functions (no matter how plausible) would also mitigate the extent of the Lucas critique, which (taken literally) would invalidate a comparison across regulatory regimes.

to extend credit because increasing the capital base may be more costly than alternative funding sources at the margin (that is, as compared with the deposit base). This is the case if there is a liquidity premium. In Aguiar and Drumond (2007) for instance, households demand a liquidity premium to hold bank capital. This, combined with a standard financial accelerator effect, implies that introducing capital requirements significantly amplifies monetary policy shocks through a liquidity premium effect on the external finance premium faced by firms. This amplification effect is greater under Basel II than under Basel I regulatory rules. Determining the extent to which these results hold with the type of credit market imperfections highlighted in this paper is an important task for middle-income countries.



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Figure 1  
Macroeconomic Equilibrium  
with Nonbinding Capital Requirements

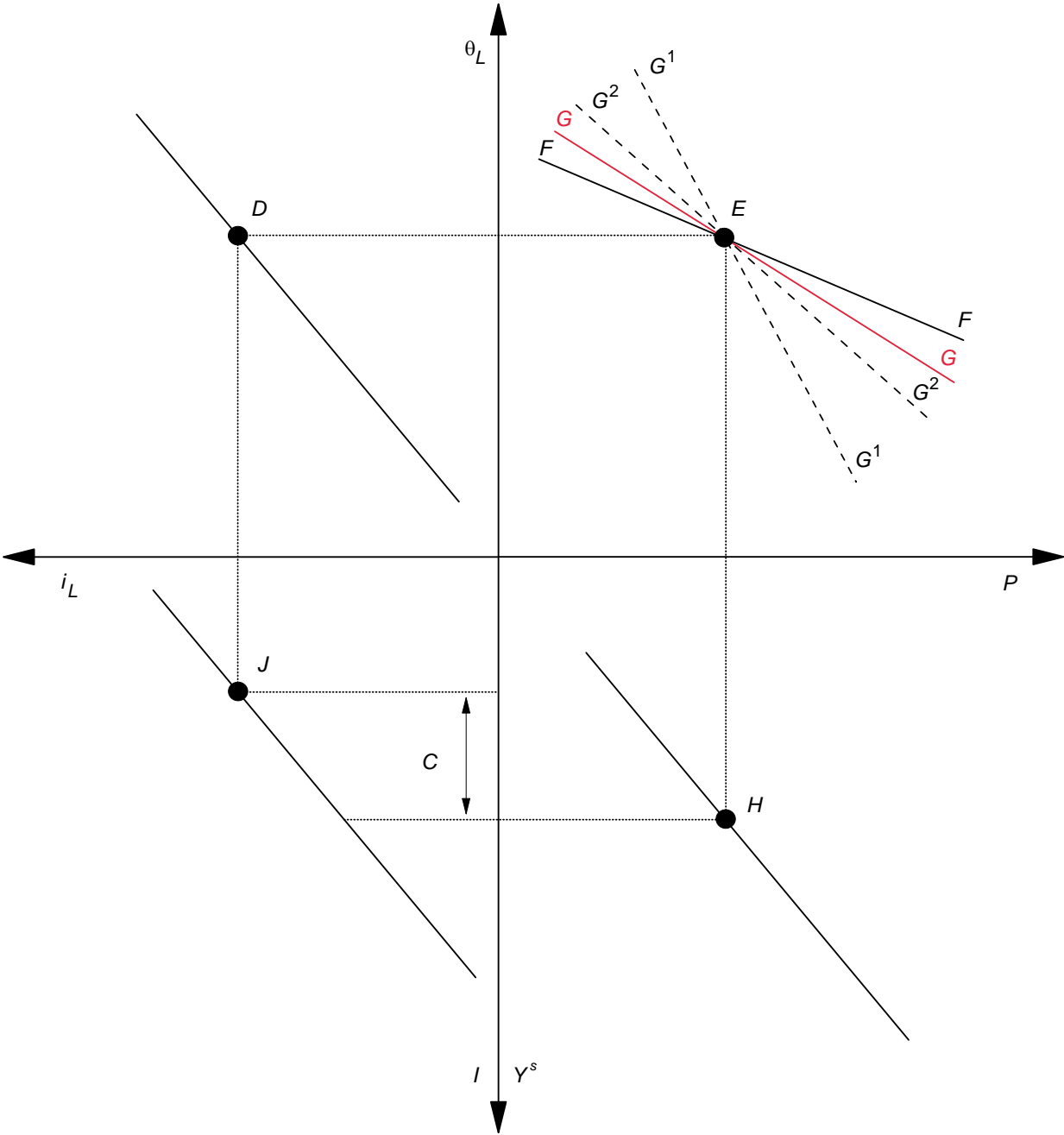


Figure 2  
 Negative Supply Shock  
 with Nonbinding Capital Requirements

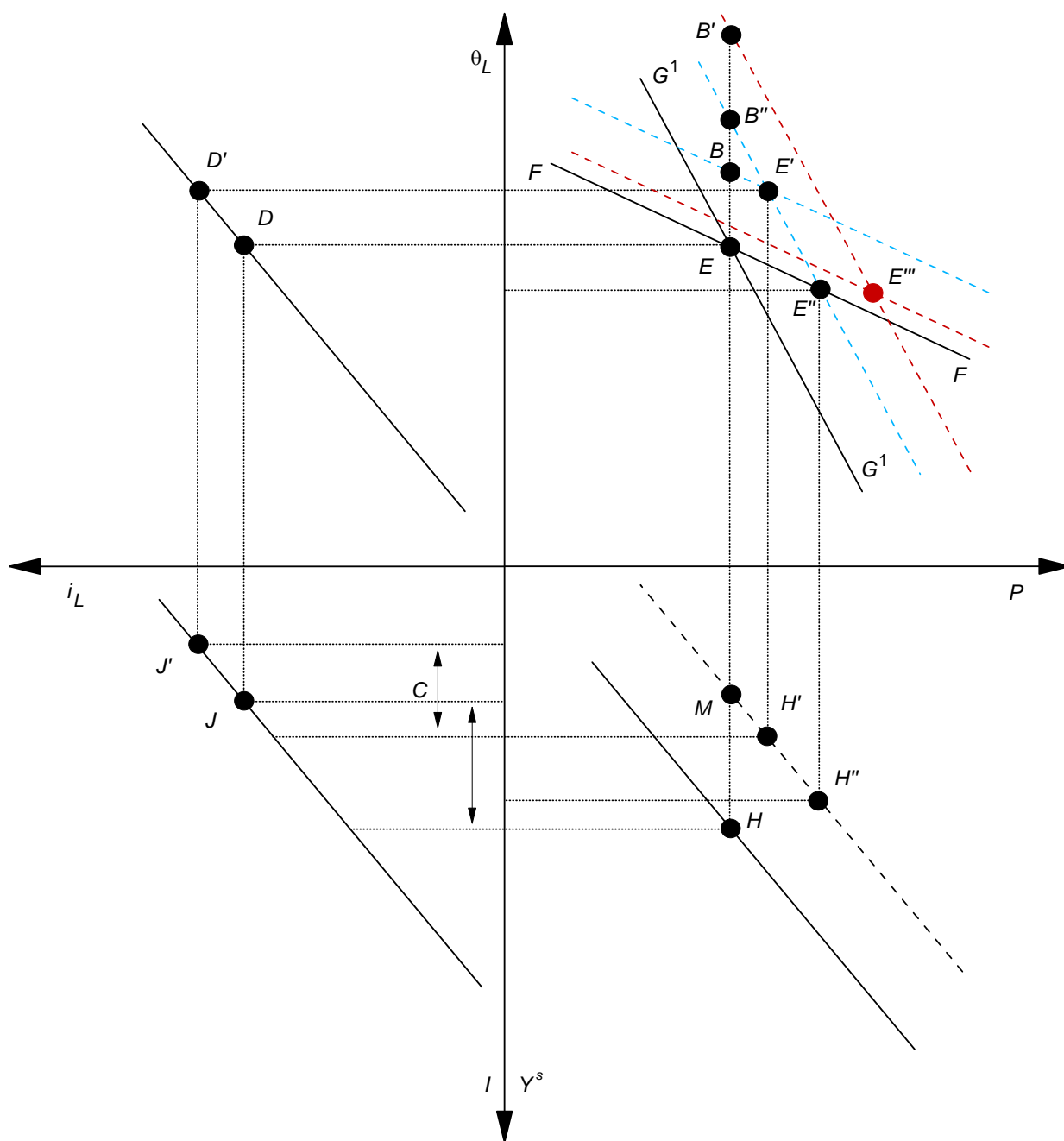


Figure 3  
Increase in the Refinance Rate  
with Nonbinding Capital Requirements

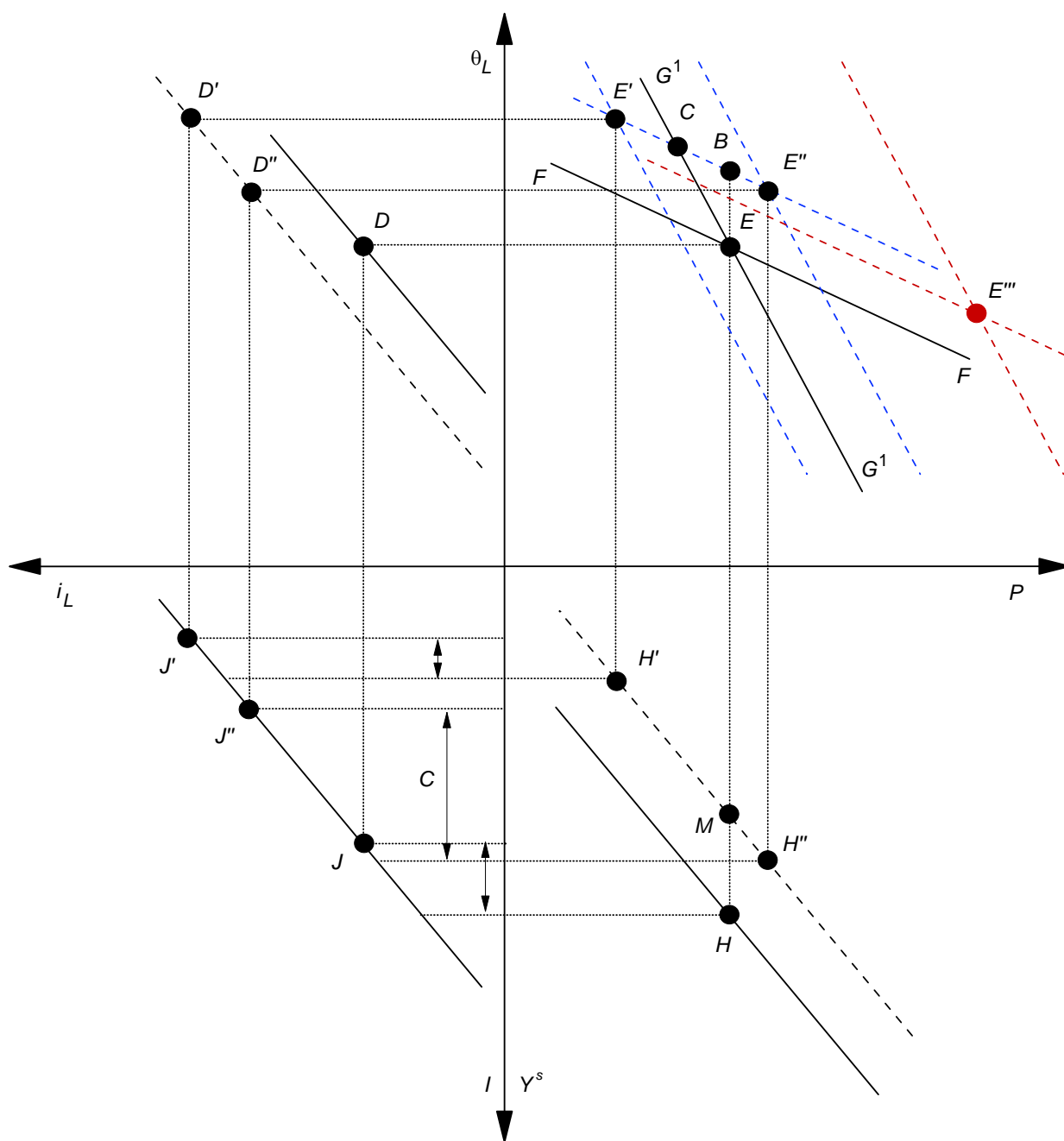


Figure 4  
Increase in the Capital Adequacy Ratio  
with Nonbinding Capital Requirements

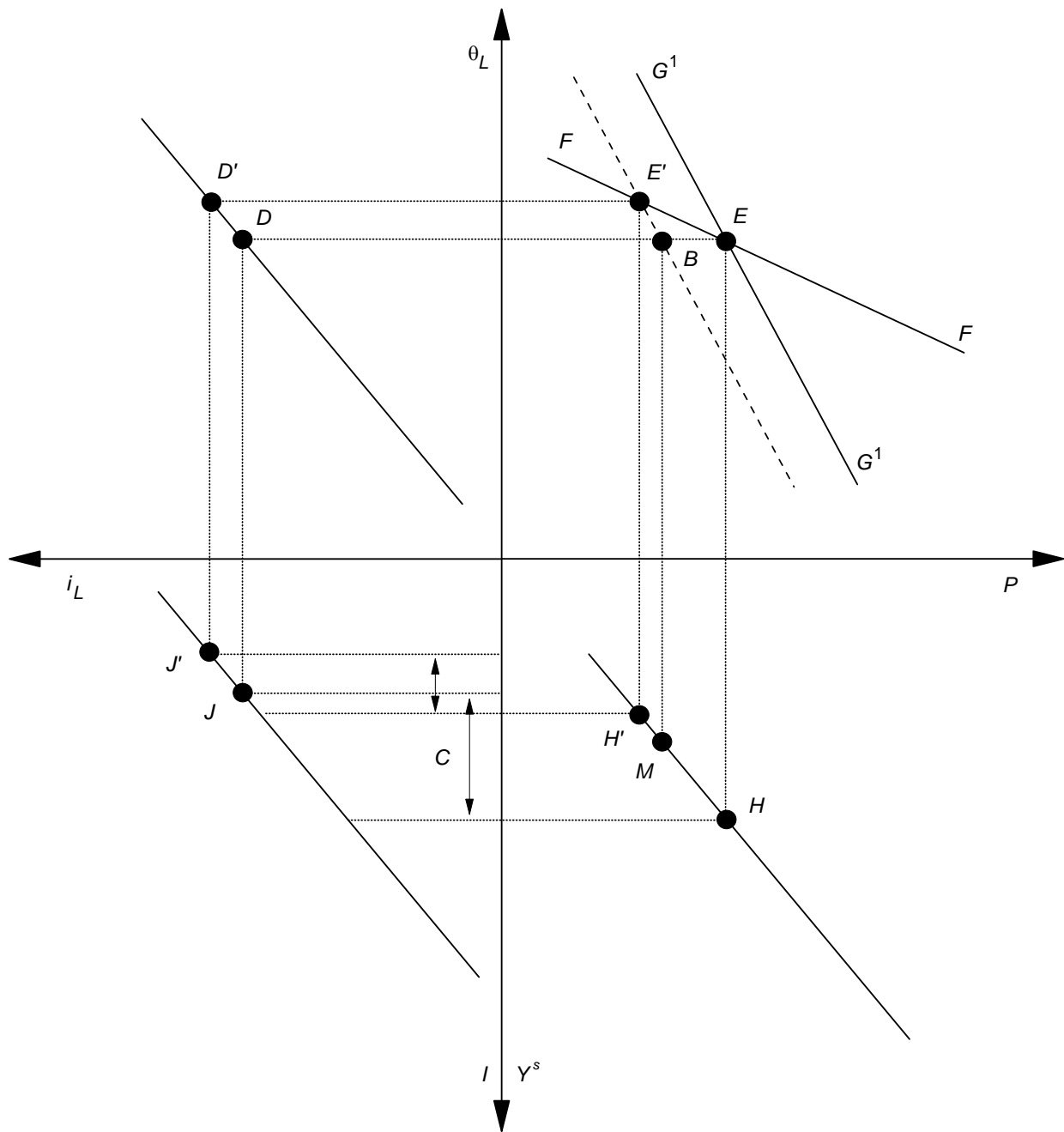


Figure 5  
Macroeconomic Equilibrium  
with Binding Capital Requirements  
(Basel I Regime)

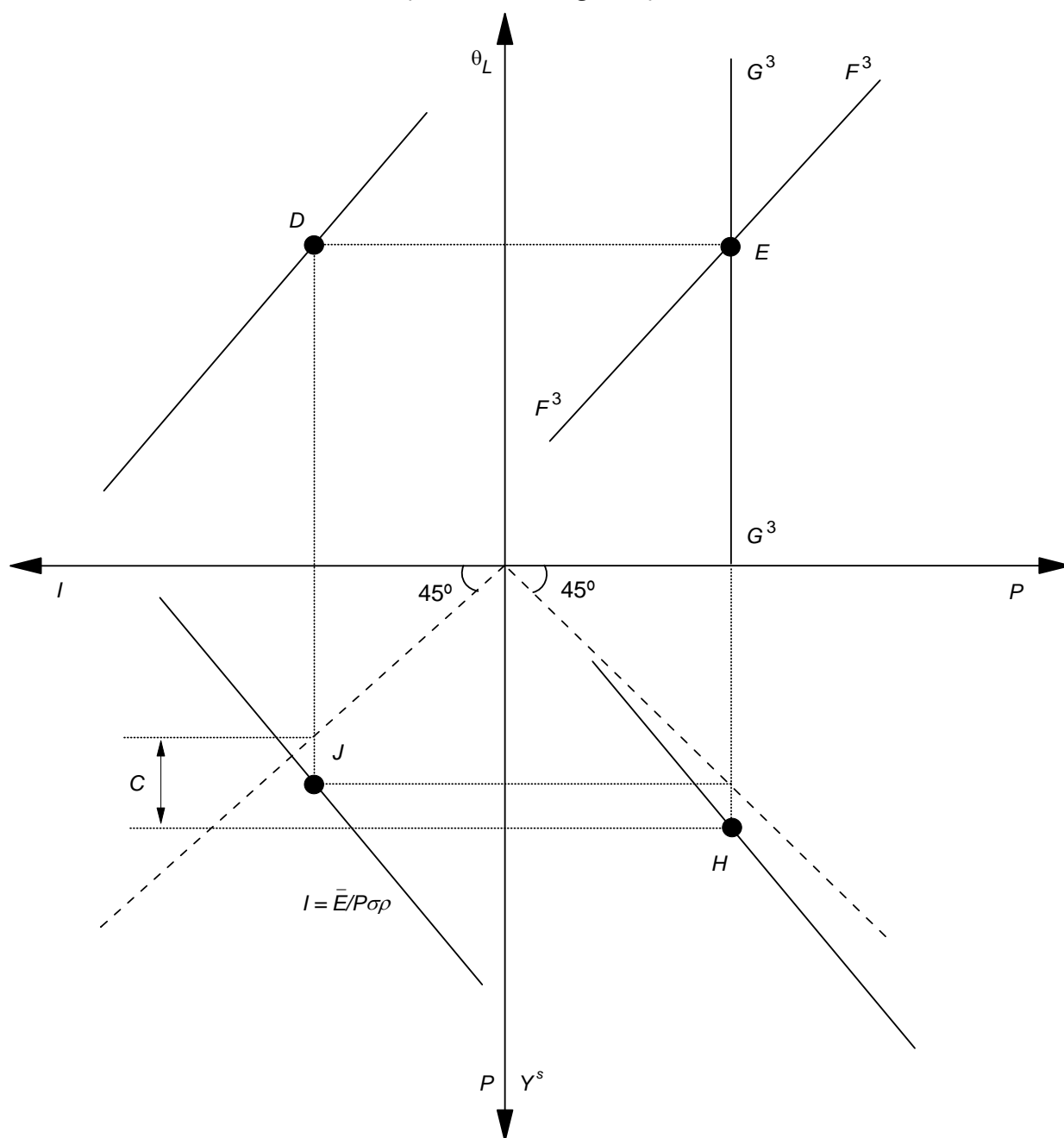




Figure 6  
 Negative Supply Shock  
 with Binding Capital Requirements  
 (Basel I Regime)

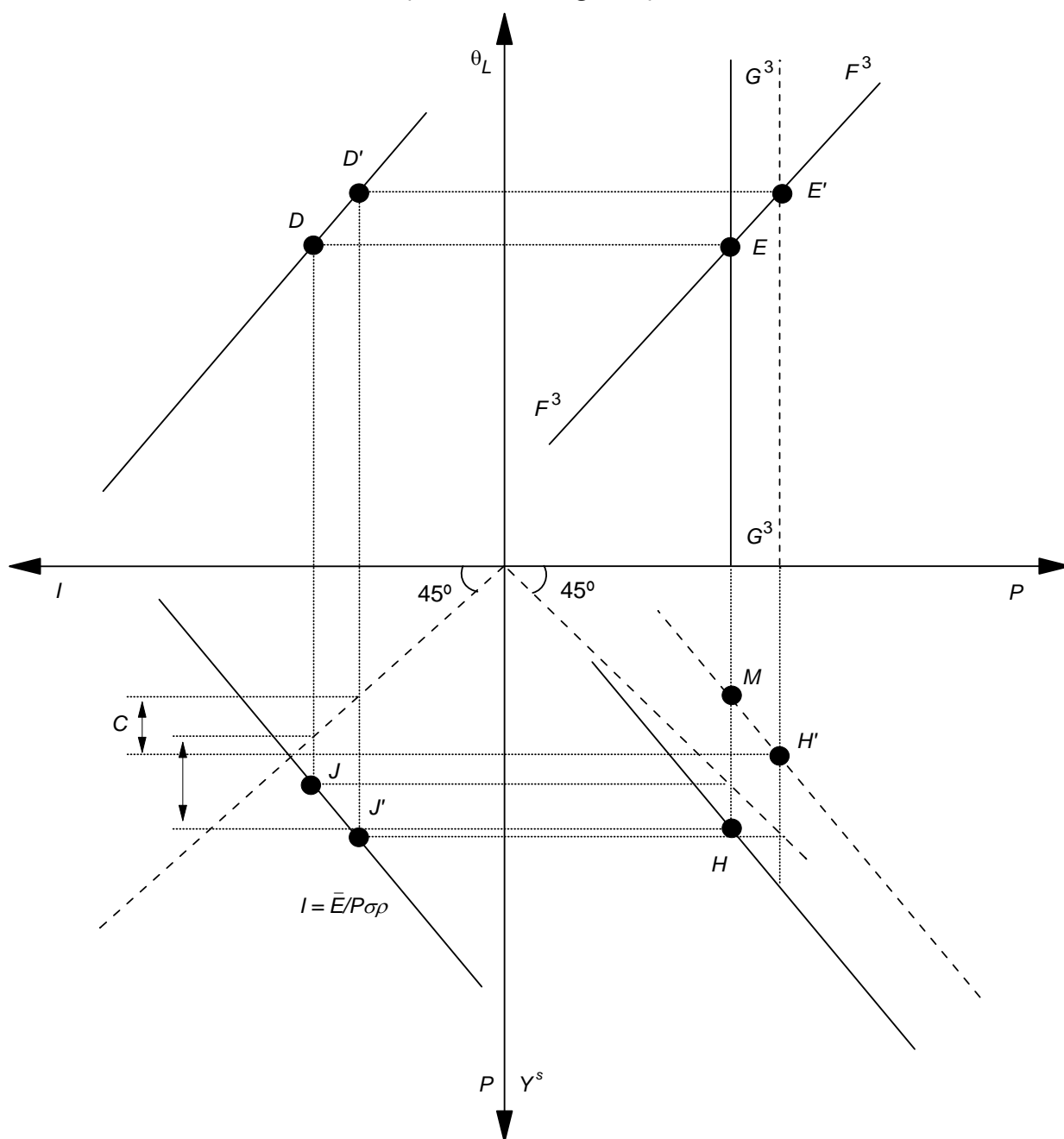


Figure 7  
 Increase in the Refinance Rate  
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 (Basel I Regime)

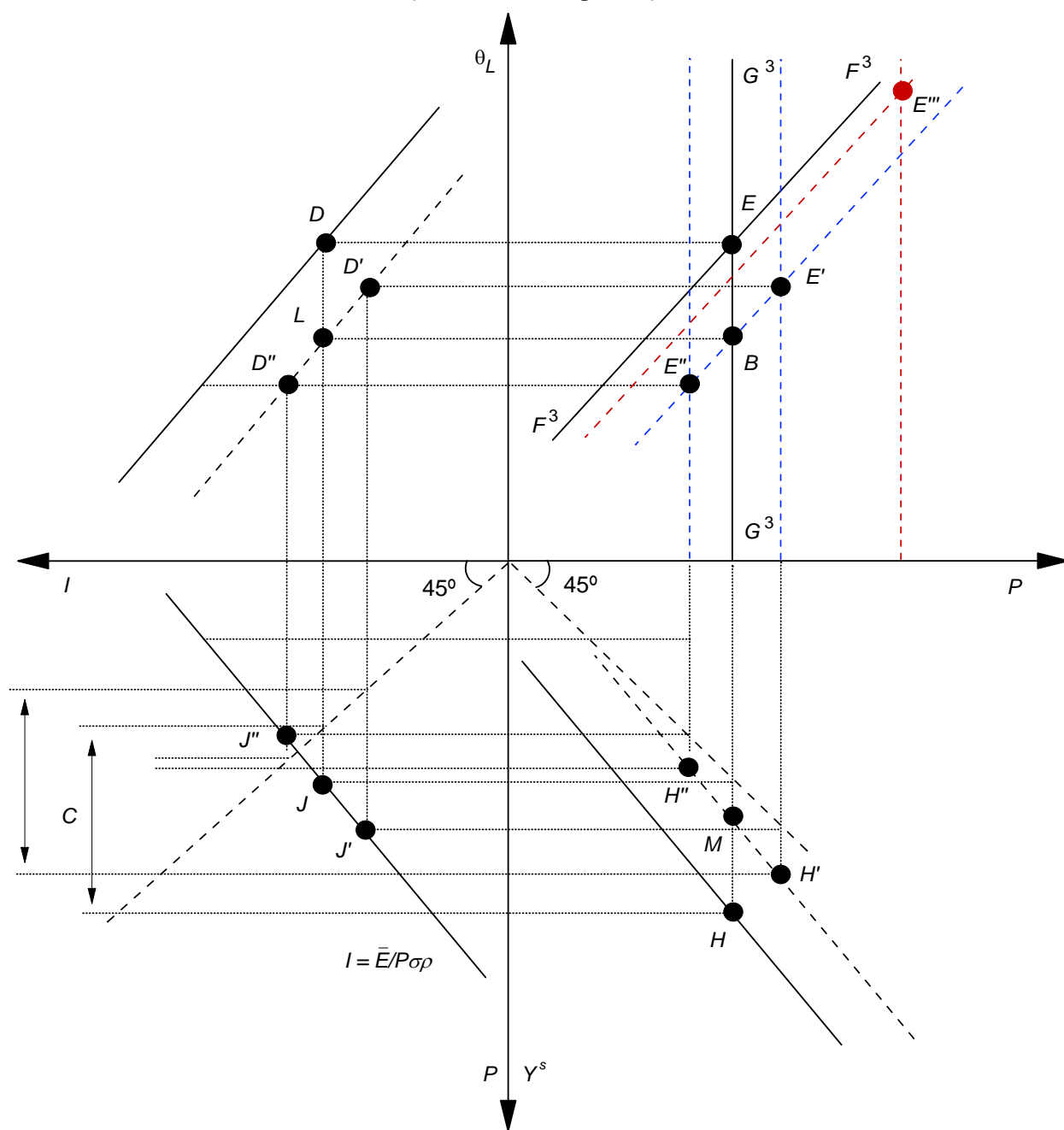


Figure 8  
Increase in Capital Adequacy Ratio  
with Binding Capital Requirements  
(Basel I Regime)

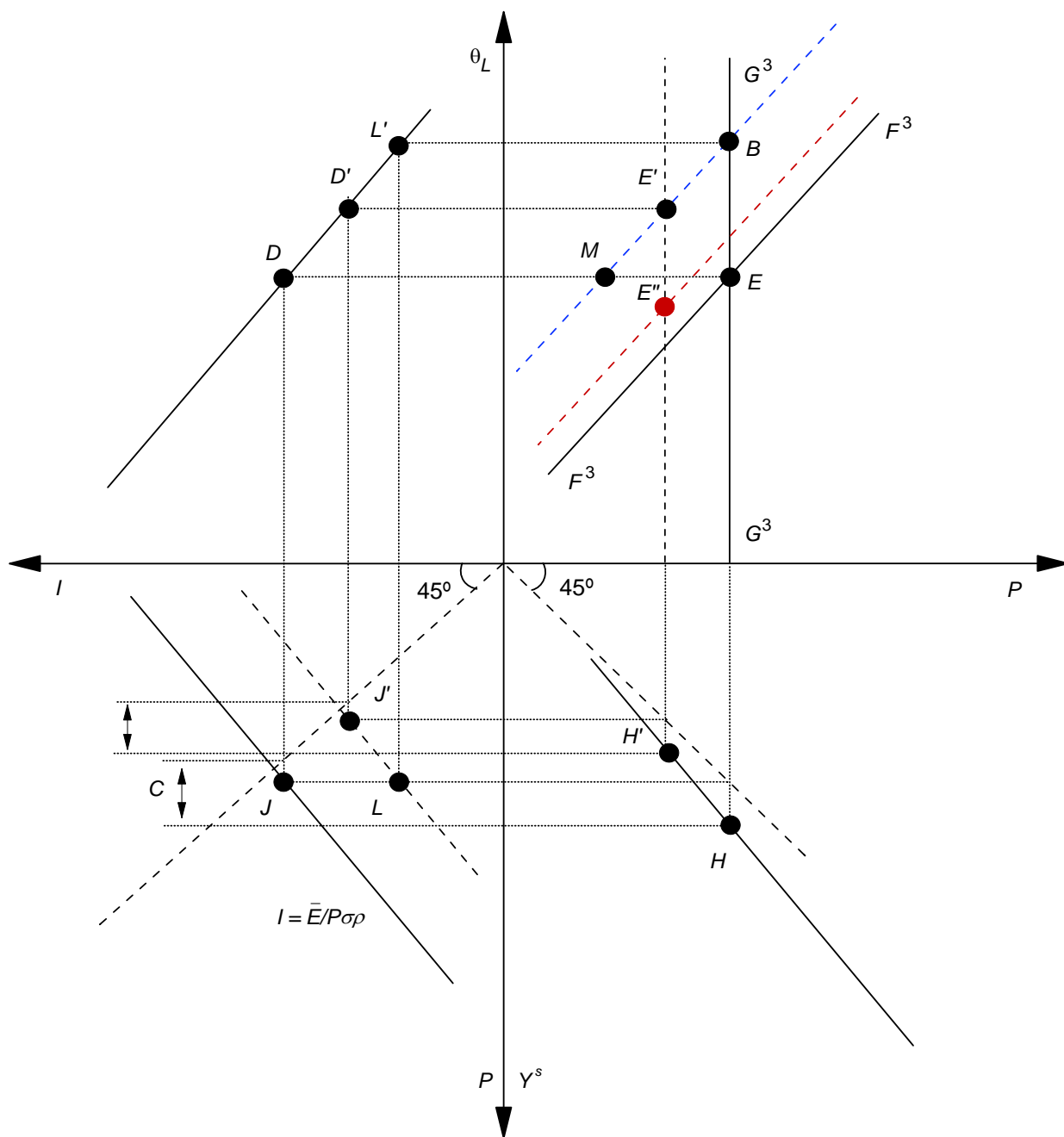


Figure 9  
Macroeconomic Equilibrium  
with Binding Capital Requirements  
(Basel II Regime)

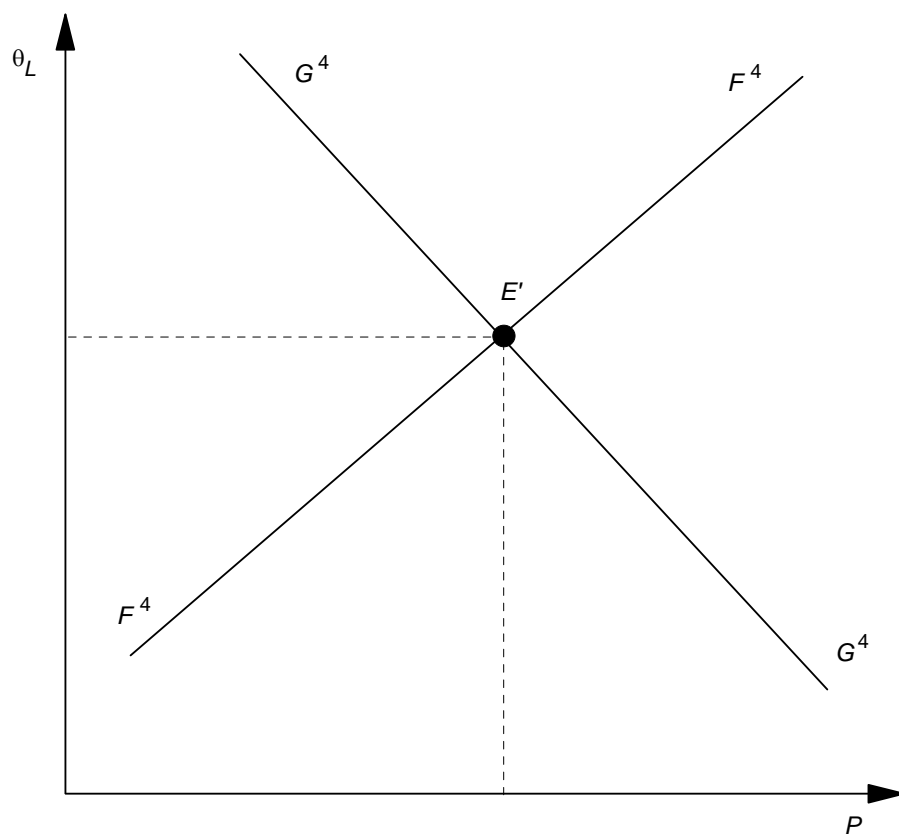


Figure 10  
Negative Supply Shock  
with Binding Capital Requirements  
(Basel II Regime)

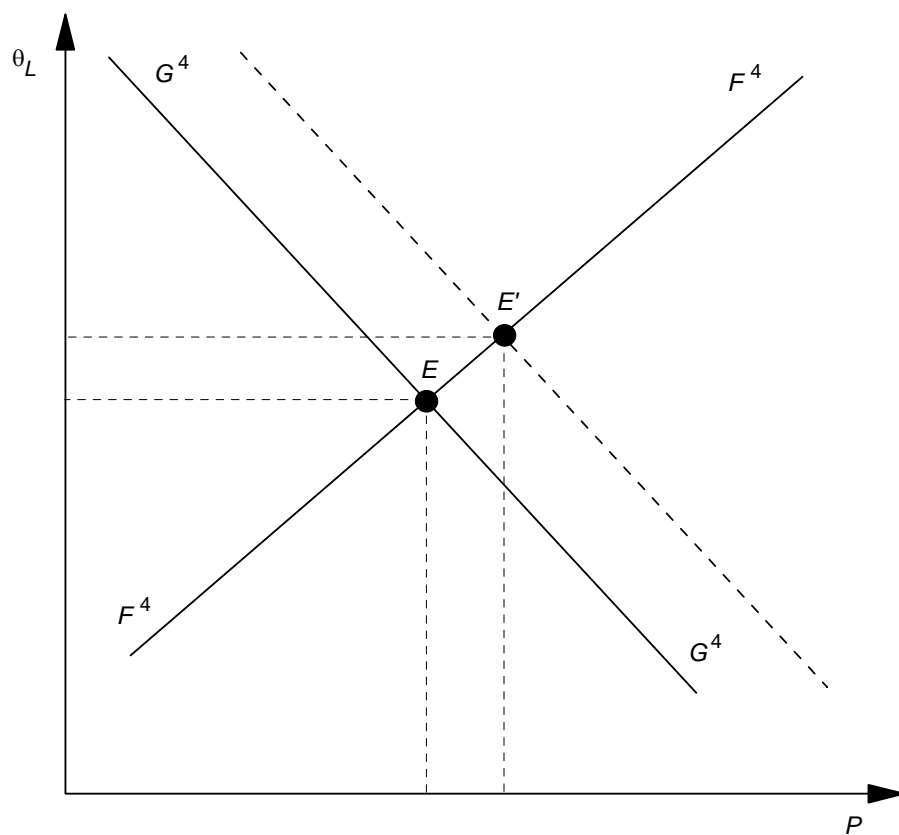


Figure 11  
 Increase in the Refinance Rate  
 with Binding Capital Requirements  
 (Basel II Regime)

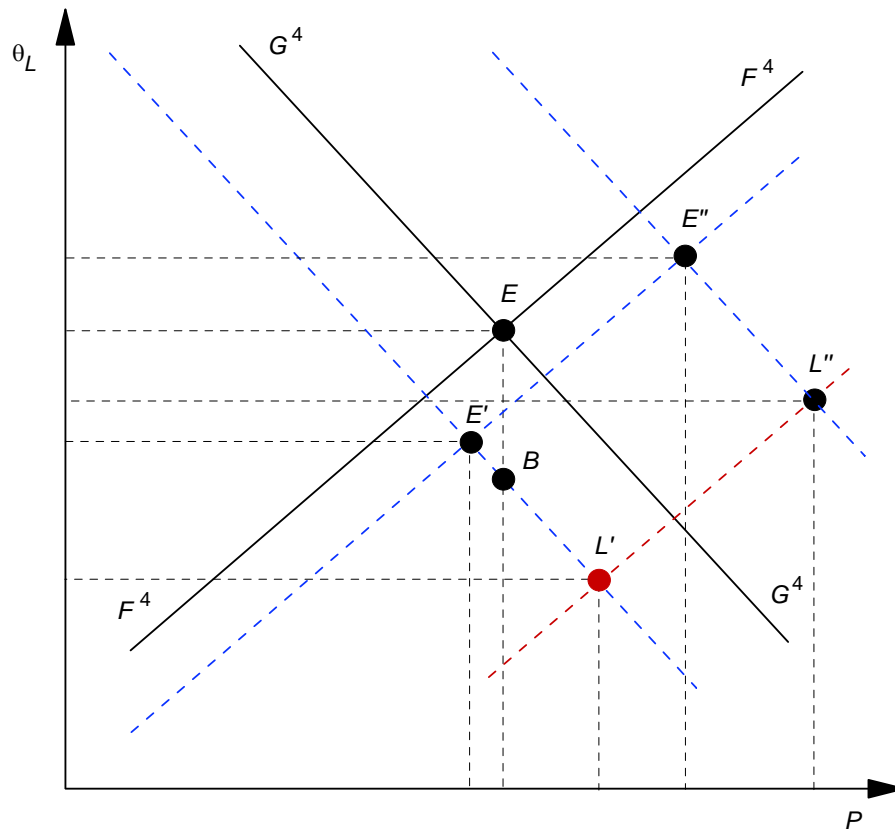


Figure 12  
Increase in Capital Adequacy Ratio  
with Binding Capital Requirements  
(Basel II Regime)

